Are electrokinetic methods suitable for the treatment of rising damp?

Yves Vanhellemont[1], Jan Bolhuis[2], Michael de Bouw[1], Samuel Dubois[1], Barbara Lubelli[2], Linda Miedema[2], Rob van Hees[2]

(1) Belgian Building Research Institute (BBRI)
(2) Technical University Delft (TUDelft)

Abstract

The treatment of rising damp is an important issue when dealing with the conservation and restoration of historic buildings. The most effective solutions for the problem of rising damp are usually very 'invasive': depending on the method, there might be a substantial loss of authentic materials, the intervention may have a significant impact on the stability of the construction, there could be a mild to very important visual impact, and the intervention might be irreversible. An efficient treatment for rising damp, without these disadvantages, would therefore be more then welcome. At present, several companies offer such a solution, in the form of so-called 'electrokinetic' methods. Within the research project EMERISDA [E1] (Effectiveness of Methods against Rising Damp), on-site measurements have been carried out on more sites, in order to evaluate their effectiveness. On one of the sites, the effectiveness of such an electrokinetic method has been compared to more conventional injections of water repellent agents.

1. Research aim

1.1. Subject of the research

The point of attention are the 'electrokinetic dehumidification techniques', whose general definition is a method where rising damp is being 'pushed back' by using electromagnetic waves. A central device emits these waves and needs to be operational as long as one wants to protect the masonry against rising damp.

Other names for this technique, such as 'electromagnetic' or 'electrokybernetic' methods have been observed as well in the commercial literature. The world 'electrokinetic' is the one in use in this article.

We were not able to extract a 'uniform' explanation of the principle of these devices from the commercial literature. Sometimes one refers to the technique as a wireless form of (active) electro-osmosis [D1, W1, W2, W3, W4]. A somewhat odd comparison, since an electromagnetic wave is a fluctuating electromagnetic field, while electro-osmosis uses a steady (static) electric field.

In one particular case, the supplier states that the waves influence the (tetrahedral) molecular structure of water, which in its turn would change the density, surface tension and evaporation rate of the humidity in the masonry.

1.2. Aim of the research

The aim of the research is to evaluate the effectiveness of the electrokinetic method on the scale of a building (not in laboratory), as this technique is specifically designed to act on the larger scale of a building (typically these devices have an action radius of about 10 metres), instead of small laboratory scale models or samples.

It was specifically not the aim to research the theoretical background of the method, nor it was intended to perform a research on the devices themselves, for instance to study the properties of the electromagnetic waves themselves (frequency, amplitudo, …).

2. Some initial thoughts about electrokinetic dehumidificaction

Some fundamental issues and questions are mentioned in the following, although the aim of this research was not to investigate the theory behind this dehumidification method.

2.1. Action of an electric field on a water molecule

Water molecules are electric dipoles. Therefore, they can interact with electric fields, be it constant, steady fields or fluctuating fields (electromagnetic waves).

For dehumidification, it is required that water molecules migrate under the influence of an electric field. This is not evident under the influence of a constant and homogeneous electric field, because in that case the net force on an electric dipole would be zero.

When the electric field is constant, although it shows a gradient on the scale of the dipole, the water molecule could experience a net force, and could therefore start to move. It is however definitely hard (or even impossible) to obtain field gradients on molecular scale, when employing macroscopic means (large electrodes, as in the case of electro-osmosis).

In the case of electromagnetic waves, the resulting force on a water molecule is always zero, because of the fluctuating nature of such an electric field: the average field is zero, and therefore also the average force on a charged particle, or on a dipole.

This explanation does not take into account possible polarisation effects between water and pores in a solid material, as is for instance described and measured in [S1]. Even if such polarisation effects exist, it is still not evident to employ them (by inversing the tension, for instance) for the dehumidification of masonry [D1, W1, W2, W3, W4]. It would lead us too far to discuss this in detail, as this is not the main topic of this article. But regarding possible polarisation effects between water molecules and charges in the pore walls, an oscillating electromagnetic field would still exerce no net force, nor on charges, nor on water molecules, therefore not being able to cause any migration of water molecules.

2.2. The Structure of the water molecule

The dipole character of a water molecule is linked to its tetrahedral structure (charge asymmetry of the molecule). This dipole character is definitely influencing many specific physical properties of water, such as its rather high surface tension and therefore relatively low evaporation rate.

It is logic to assume that changing the structure of a water molecule, the change influences the surface tension, evaporation rate and density of water, and also the capillary uptake of water by a porous material.

The question remains if electromagnetic waves are effectively able to change the structure of a water molecule. When using electromagnetic waves, one causes a vibration of the dipole structure around its equilibrium (tetrahedral) structure. Especially when using frequencies near the eigenfrequencies of one of the three main vibration modes (eigenmodes) of the molecule, one would cause a strong resonance in one (or more) vibration modes. The wavelengths, corresponding to these waves, are around 2.7 and 6.3 µm [A1].

The mean dipole moment, and therefore the interaction between water molecules, would however remain the same during such vibrations. Hence, none change at all is expected of density and surface tension of the water. On the other hand, these vibrations would cause the heating of the water (transfer of the submolecular vibration energy to kinetic energy of the molecule itself), therefore possibly indirectly causing an acceleration of the drying of the wall.

It is needless to say that such a heating effect would be totally undesirable, because of the danger for humans, animals and plants in the vicinity of the wave-emitting device.

2.3. capillaries in stones, mortars, humans, animals and plants.

Humidity transport does not only take place in capillaries in stonelike materials. Plants and animals contain numerous capillaries through which transport of water, nutrients, … takes place. The size of blood vessels varies from a few µm to several millimetres. The finest (capillary) vessels are therefore comparable in size to pores that we observe in many natural stones, mortars and bricks.

Even though the flow of blood in blood vessels is not caused by the capillary forces in these vessels, one might at least expect a perturbation of the blood flow in the human body in the vicinity of an electrokinetic dehumidification device (if they would influence the flow of water in pores).

The water transport in plants is also not (entirely) driven by capillary rise, but the sap-vessels in plants have also dimensions comparable to the capillary veins in humans and animals and pores in stone-like materials. Therefore, one would again expect an influence of an electrokinetic dehumidification device on the water transport in nearby plants.

If the electrokinetic dehumidification works, it could have a (hazardous?) influence on the blood- or humidity transport in living organisms, making the method unsuitable to long-term application in buildings.

2.4. Conclusion

We would like to emphasize that these phenomena have not been studied in the project. Even though the above questions could create doubt around the reliability of electrokinetic dehumidification methods, ‘the proof of the pudding is in the eating’: an evaluation of the effect of these devices on a building suffering from rising damp will demonstrate directly the effectiveness of the method.

3. Method

To study on site the effect of (any) technique against rising damp, it is necessary to apply the technique to a building, where all side conditions remain unchanged during the testing period: therefore, no change in climatic conditions (ventilation rate, room air temperature, etc) and no material changes (i.e. restoration of mortars, stones, or application or renders, paints, …) should occur.

Within the EMERISDA project, several buildings have been selected, according to the above mentioned criteria, to be used as case studies. The moisture and salt content and distribution in the wall before the application of the devices was measured, according to the method described in [L1].

The authors applied the gravimetric test to measure the moisture content (drying samples at 60° C). The salt content was indicatively assessed, by measuring the hygroscopic moisture uptake (HMC) of the samples after 4 weeks storage at 20 C 95% RH. Both the MC and HMC content were calculated as

% of the dry weight of the samples. These measurements were carried out on regular intervals (typically each 6 monts or each year). In two cases only an elektrokinetic device was installed. In the third case, such a device was installed on one part of the building. On another part of the building, far away from the electrokinetic dehumidification device, conventional injections with different injection products were carried out.

4. Results

4.1. Paardenmarkt, Delft, Netherlands

The former Artillery warehouse 'Paardenmarkt' is a listed monument in the centre of Delft. It was constructed in the 17th century. The buildings are constructed in brick masonry, and are subject to rising damp and salt crystallisation. The salts cause the typical decay of disintegration of renders and flaking of paint. It is worth mentioning that the groundwater level is high. Samples have been taken at 3 locations within the action radius of two electrokinetic dehumidification devices (installed by the supplier). The action radius of a device is usually in the order of 10 metres, and is defined by the supplier as radius of the sphere around the device, in which the action of the device can be felt.

A reference location, within the same building, has been selected outside the action radius of the devices. The moisture and hygroscopic moisture distribution at the different locations show the presence of rising damp; additionally, at some of the locations, also rain water penetration is present in the upper part of the wall.

-

Figure 1: Paardenmarkt (Delft, Netherlands), exterior and damage in the interior

The graphs show the moisture content MC, in function of height and depth, for four of the sampling locations, before and 10 months after the application of the device. Further information on the set-up of the research and detailed results can be found in [L2].

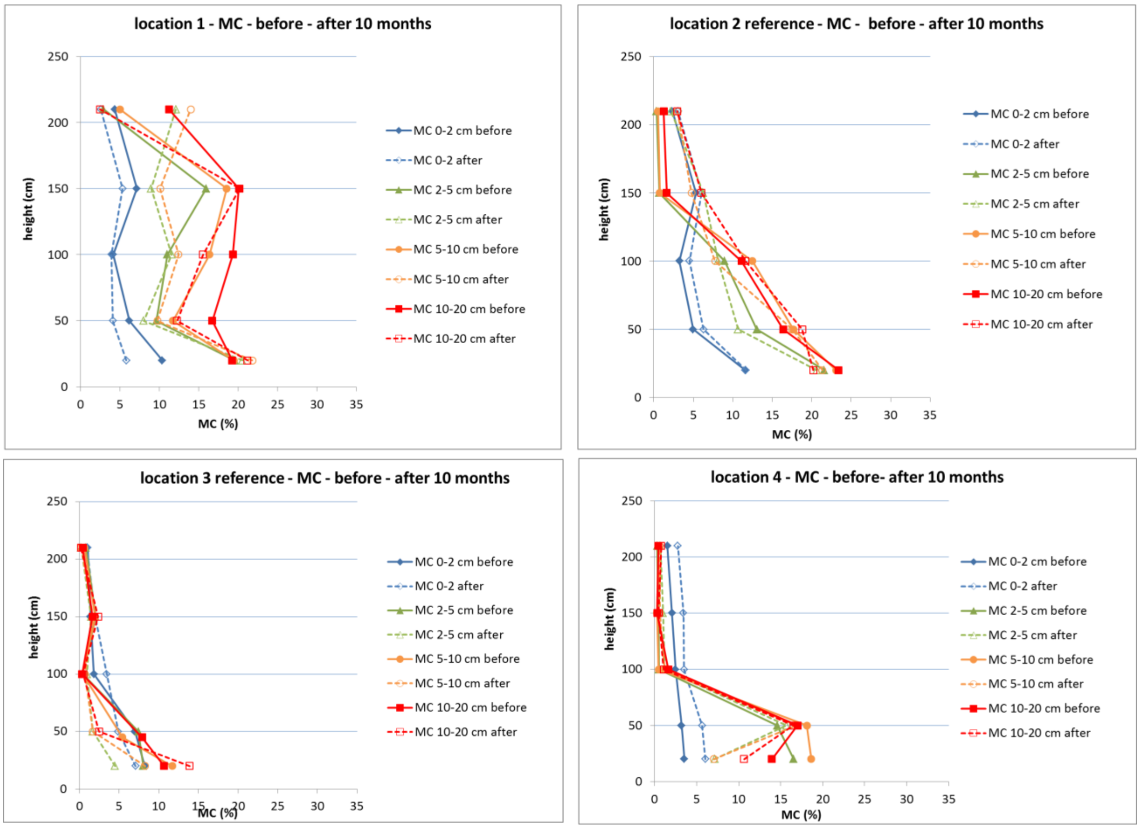

Figure 2: Moisture (MC) distribution at 4 locations (2 reference and 2 within the radius influence of the electrokinetic device) the walls of the Paardenmaarkt in Delft before and 10 months after the application of electrokinetic devices. Solid lines depict the situation before the intervention, dashed lines depict the situation after intervention.

4.2. St Bavo church, Haarlem, Netherlands

The construction of the St Bavo church in Harlem started around 1400. The gothic church is currently protected as a monument. The walls is constructed in brick masonry, with details in natural stone. The interior walls were rendered.



Figure 3: interior of the St Bavo church in Haarlem (Netherlands), with details of the damage

Inside, lots of damages are evident, especially at the lower part of columns and walls. The main decay consists on salt efflorescence, crypt-efflorescence and peeling of the paint layer. Such degradation phenomena are often seen in the presence of rising damp.

An electrokinetic dehumidification device has been installed inside the church by the supplier. Two measuring points haven been chosen within the working radius of the device (location 1 and 2) and one outside of this action radius (location 3). The measurements at these locations, before the installation of the dehumidification device, show clearly higher humidity content deeper in the wall, and nearer to the floor, thus indicating the presence of rising damp.

A year after the installation of the electrokinetic dehumidification device, Sampling in location 1 was 70 cm away from the first sampling place, because of the presence of an old tombstone. The following graphs show the evolution of the MC in depth in the walls

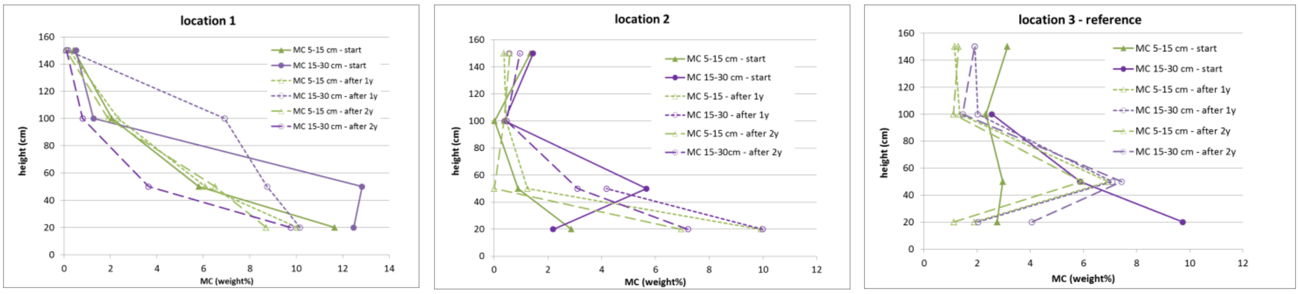

Figure 4: MC distribution at 3 locations before and 1 and 2 years after the application of the electrokinetic device. Location 3 is outside the action radius of the electrokinetic device. Solid lines depict the situation before the intervention, dashed lines depict the situation after intervention.

4.3. St Martin's church, Genappe, Belgium

This classicist church dates from the 18th century. It is a typical construction, mainly in brick masonry. The lower parts of the walls, and the window frames, are in local natural stone, such as the so-called 'Belgian blue stone' (a kind of dense, grey-blue coloured limestone), and sandstone. Opposite to its simple exterior, the interior is decorated with a high and elaborate wooden panelling in Louis XV-style, both in the church and the choir, together with stucco ceilings and mural paintings.

Figure 5: exterior and interior of the St Martin's church (Genappe, Belgium)

The church stands at a distance of about 20 meters from the Dijle River. The groundwater level is very high, in the order of a meter below the ground level. The church is standing with its foundations in the ground water, causing rising damp everywhere in the church. Because of the wood panelling inside the church, the humidity is only able to evaporate on the exterior of the church. Moreover, because of the closed space between the walls and the wood panelling, the air in this space is particularly humid. This permanent humidity between the panelling and the wall causes damage, such as biological degradation and a large deformation of the wooden elements.

The walls have a thickness of 87 cm, and are in need of treatment, to preserve the valuable wood panelling inside of the church. No treatments against rising damp have been carried out yet in the past.

Measurements before intervention show clearly how the humidity content rises when samples are taken deeper in the wall. The humidity level reaches a maximum right behind the wood panelling, which is logic, as this part of the wall is located at an important distance of the evaporating surface (the outer façade). The humidity content in the wall decreases when sampling at a higher level above the ground.

The HMC remains low, much lower than MC. This and the shape of the graphs indicate that the humidity is caused by rising damp.

Figure 6: location of the test zones (numbered 1 to 5) on the north outer wall of the St Martin's church, Genappe. They are hardly exposed to driving rain.

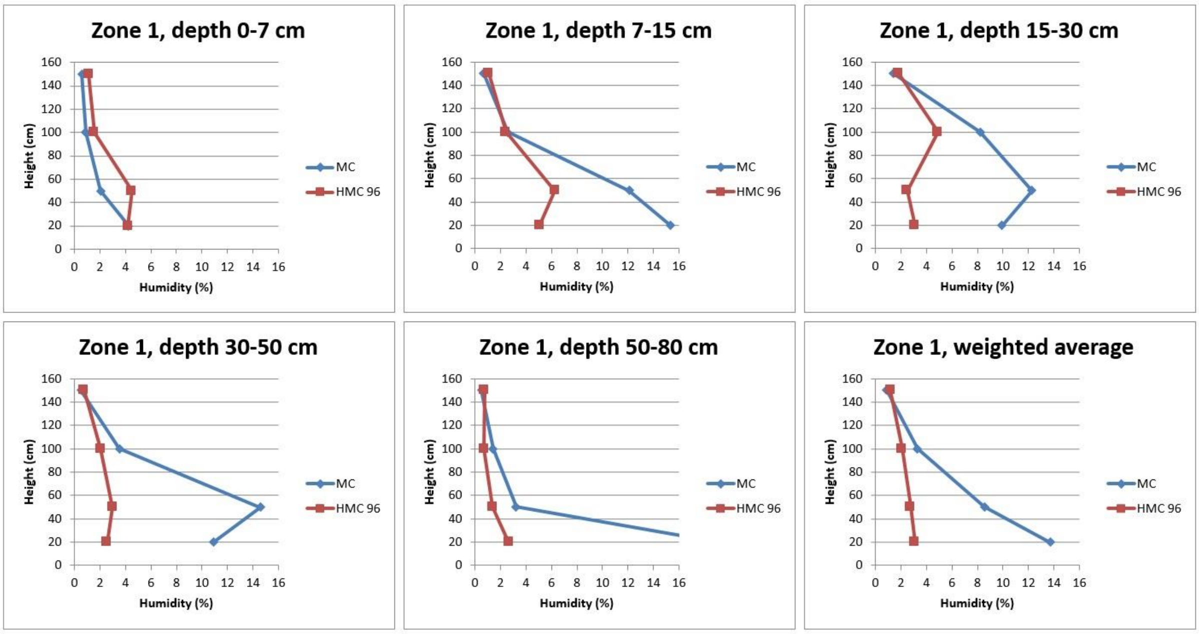

Figure 7: a typical moisture distribution in the St Martin's Church.

In five test zones, different methods against rising damp have been applied.

- Zone 1: a liquid injection product, 10% concentration, of mainly siloxanes in a solution in isoparaffine. Per m² horizontal wall surface, a quantity of 13 à 14 litres was injected, through boreholes of 12 mm diameter, at a distance of 12 cm from each other.
- Zone 2: an injection cream, water-based, 80% concentration, of silanes. Per m² horizontal wall surface, a quantity of about 1 litre was injected, through boreholes of 12 mm diameter, at a distance of 12 cm from each other.
- Zone 3: an injection cream, water-based, 65% concentration, of silanes and siloxanes. Per m² horizontal wall surface, a quantity of about 1 litre was injected, through boreholes of 12 mm diameter, at a distance of 12 cm from each other.
- Zone 4: a liquid injection product, 10% concentration, of mainly silanes and siloxanes in a water-based emulsion. Per m² horizontal wall surface, a quantity of 13 à 14 litres was injected, through boreholes of 12 mm diameter, at a distance of 12 cm from each other.
- Zone 5: electrokinetic device, installed by the supplier inside the church, near the outer wall.

During 1.5 years, in three campaigns, the moisture content was monitored, in function of height and depth in the wall. The average moisture content values are presented in figure 8

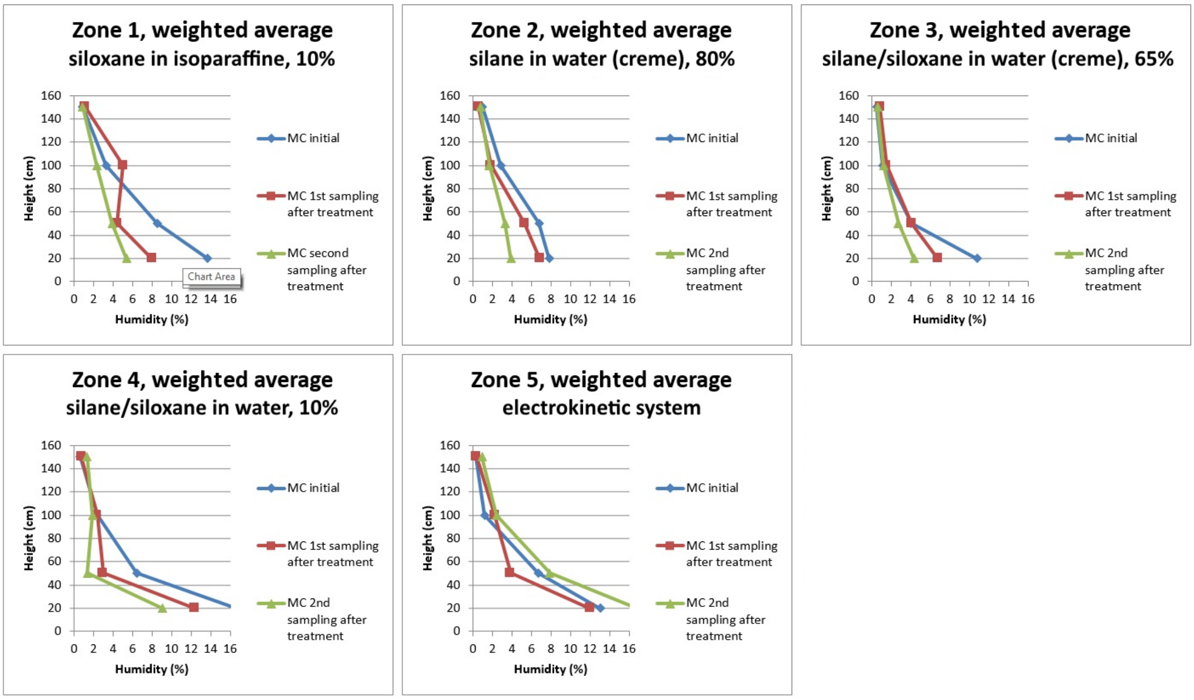

Figure 8: evolution of the average moisture distribution in the 5 test zones during 1.5 years.

5. Discussion

1.1. Paardenmarkt, Delft

The evolution of the moisture content at the location within the radius of influence of the electro-kinetic devices is comparable to that of the reference locations. Small changes in the MC are observed. The effectiveness of the method 10 months after its application can thus not be confirmed.

1.2. St Bavo church, Harlem

No significant differences in the evaluation of the MC in the wall can be observed between location 1 and 2 (under the influence of the dehumidication device) and 3 (reference). At location 2, in depth and in the lower part of the wall, the MC has even increased. Also in this case the effectiveness of the electrokinetic method cannot be confirmed.

1.3. St Martin's church, Genappe

The result for the test zones with conventional injections are very clear: in all such zones, the measurements indicate a systematic decrease of the moisture content of the wall, at all depths and heights. It definitely shows that it is possible to successfully inject thick masonry. At the end of the measuring campaign, the moisture content has not decreased sufficiently to the desired level of maximum 3%. This moisture content is in Belgium generally considered as the maximum that may be tolerated in masonry [H1].

However, thick walls (almost 90 cm) that have hardly any evaporation possibilities on one side (due the presence of sculpted wooden panels on the inside of the building) dry out very slowly. It is therefore comprehensible that the total drying out of the walls could not be obtained within the course of the project. As a comparison: the period for drying out a wall of a 30 cm thick, that can dry on both sides, is estimated between a couple of months and one year [7]. One can imagine the important drying period for a wall that is almost three times thicker, and that can only dry on one side.

On the other hand, the zone, treated with the electrokinetic device, on the other hand, did not show a significant reduction in humidity. Moreover, after the flooding of the church (june 2016) a major increase of the humidity has been measured in zone 5. This increase has not observed in the zones with the injections, even though the water level during the flood was equal to the level of the water in the zone with the elektrokinetic device.

6. Conclusive discussion

The treatment of rising damp is an essential part of the conservation/restoration practice of historic buildings, it is also evidently of main importance in the rehabilitation of existing buildings in general. Within the EMERISDA-project, we were able to perform profound on-site evaluations of the so-called electrokinetic methods. These methods are popular, as they do not have an important impact on the heritage value of a building (no removal of historic materials, and fully reversible) and are easy to install. Nevertheless, are these devices effective, i.e. are they able to reduce the humidity in masonry in the vicinity of the device?

There are several reasons why they could not have the desired effect. The aim of the research was to look directly to the effect of the electrokinetic devices on rising damp in masonry. Therefore, the conclusion deals with the results of the tests and on site assessment.

The tests showed that these devices did not cause any significant nor consistent decrease of the moisture content of the masonry; differently, conventional injections, tested on the same test case, were shown to be effective.

Based on site field investigations and monitoring campaigns, the final remark is that electrokinetic methods are not a valid alternative for existing techniques, such as injections or mechanical cut of the wall.

7. References

[A1] see any standard physics learning book, i.e. G. Aruldhas, P. Rajagopal, Modern Physics, PHI Learning, Delhi, 2005, p. 179

[D1] L. Demberger, Elektroosmose contra Elektrolyse, Köln, Baugewerbe, n° 1-2, 1992

[E1] www.emerisda.eu

[H1] S. Herinckx, Y. Vanhellemont, Technical information note 252, Humidity in Buildings – treatment of rising damp, BBRI, 2014

[L1] B. Lubelli, R.P.J. van Hees, J. Bolhuis, Effectiveness of methods against rising damp in buildings: results from the EMERISDA project, in this special issue

[L2] B. Lubelli, R.P.J. van Hees, L. Miedema, M. Fugazzotto, A. Sardella, A. Bonazza, "Electro-physical" methods to stop rising damp. Assessment of the effectiveness in two case studies, in I. Rörig-Dalgaard and I. Ioannou (eds), Proceedings of the International RILEM Conference on

Materials, Systems and Structures in Civil Engineering 2016, Segment on Historical Masonry, Lyngby, Denmark, August 22-24, 2016, p.195-204

[S1] F. Sandrolini, E. Franzoni, Repair systems for the restoration of ancient buildings – dampness rise problem, Restoration of Buildings and monuments, vol. 13, no. 3, p. 161-172, 2007

[W1] F. Wittmann, Kann das Prinzip der Elektroosmose zur Trockenlegung von Mauerwerk angewendet werden? Keulen, Bautenschutz und Bausanierung, nr. 4, 1981.

[W2] F. Wittmann Le potentiel-zeta et le transport d'humidité dans les matériaux poreux. Colloque : les remontées d'eau du sol dans les maçonneries. Diagnostic, expériences de contrôle, mise en oeuvre. Parijs, Section française du Conseil international des monuments et des sites, 25 januari 1994.

[W3] F. Wittmann , W.O. Boekwijt, Grundlage und Anwendbarkeit der Elektroosmose zum Trocknen durchfeuchteten Mauerwerks. Berlijn, Bauphysik, nr. 4, 1982.

[W4] F. Wittmann, S. Madra, C. Ferraris, Versuche zur Mauertrocknung durch Elektroosmose. Zürich, Bau, nr. 2, 1984